

DENTAL EQUIPMENT TEST DURING ZERO-GRAVITY FLIGHT

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EXECUTIVE SUMMARY:

The overall objectives of this program are to establish performance criteria and develop prototype equipment for use in the HMF in meeting the needs of dental emergencies during space missions. The primary efforts during this flight were to test patient-operator relationships, patient (manikin) restraint and positioning, task lighting systems, use and operation of dental rotary instruments, suction and particle containment system, dental hand instrument delivery and control procedures, and use of dental treatment materials. The initial efforts during the flight focused on verification of the efficacy of the particle containment system. An absorptive barrier was also tested in lieu of the suction collector. To test the instrument delivery system, teeth in the manikin were prepared with the dental drill to receive restorations; some with temporary filling material and another with definitive filling material (composite resin).

The tests of the laminar-air particle containment system confirmed earlier results which showed that directing particles with laminar air into a suction receiver provided excellent control of particulates. Suction without the laminar flow was not effective, and neither was directing particles against an absorptive barrier. The best particle containment came from the combination use of the laminar-air/suction collector in concert with immediate area suction from a surgical high-volume suction tip. Lighting in the treatment area was provided by a flexible fiberoptic probe. This system is quite effective for small areas, but generalized task/ambient illumination is required. The instrument containment system (elastic cord network) was extremely effective and easy to use. The most serious problem with instrument delivery and actual treatment was the lack of time during the microgravity sequences. The restorative materials handled and finished well, considering the time available. Flexible operator foot-loop

MATERIALS

The HMF restraint table and dental power pack were installed in NASA aircraft #930 on Monday, January 22, 1990 in preparation for the Tuesday flight.

On Tuesday morning, once airborne, the dental instrument tray, mannequin and particle collectors were fixed to the restraint table and connected to the power pack. The equipment consisted of:

1. Dental instrument tray assembly
 - instrument tray with elastic cord restraints
 - straight tube, laminar air curtain under tray (21 ea, 1 mm air holes @ 20 psi)
 - dental treatment instruments
 - pressure canisters (2) for vapor particle generation and syringe
 - dental motor power pack
 - "micro" fiberoptic light source
2. Anatomic mannequin with full dentition and particle spray nozzle
3. Prototype particle collector cone with tubing, 3-way dental syringe (water, air, or combination spray), surgical HVE aspirator, and small cone mounted on a "chase" tubing for collection of debris which might escape the treatment area
4. Power pack - (mounted to floor under table)
 - 3/4 HP diaphragm air compressor
 - 2 HP vacuum source
 - rheostat (vacuum control)
 - fiberoptic light source (primary)

5. Evaluate the efficiency of an absorbent barrier to trap and contain particulates directed against it.
6. Test ability of instrument tray elastic cord restraint system to hold instruments and materials in position and determine ease of accessing instruments as needed.
7. Illuminate the treatment areas with the fiberoptic probe and subjectively determine necessary intensity and overall effectiveness.
8. Use the dental engine to prepare teeth in the mannequin for restoration, in a manner consistent with normal dental treatment. Determine subjective cutting efficiency and ability of collection system to control effluent particulates.
9. Dispense, place, cure and finish dental restorative materials in the teeth prepared in 3.8 above.

RESULTS

1. Evaluate patient-operator relationships, patient (mannequin) restraint and positioning, plus compatibility of equipment with HMF treatment/restraint table.

As previously reported, the instrument tray assembly with laminar air curtain appears to fit well within the concept of the table. The tray is fastened to the head end of the table with the universal rail clamps and is positioned directly over the patients' upper forehead. This position appears to allow reasonable access to the face and oral/maxillofacial regions. The laminar air generation tube is mounted under the leading edge of the tray and it allows the laminar air flow to be directed across the face from the forehead towards the chin and chest area and hence into the chest mounted collector. The tray position also allows equal access to the patient, instruments and materials from either side of the table.

The particle collector was supported by the chest of the mannequin and held in position with elastic straps. The connecting suction tubing was directed over the edge of the table to the power pack below. The high volume evacuator (HVE) was fastened to the table edge rail through a circular holder which kept the hose under control, yet allowed use as

As detailed in 2.2.1.2 above, the straight tube air curtain (20 PSI) diverted the emerging particles very well. The particles responded well to limited changes in direction of the curtain from horizontal downward. Much more than about 15' downward movement was beyond the range of reality considering the physical structure of a human and the fact that it would be counter productive to direct the particles down and away from the collector on the chest area.

The 1 mm holes in the tubing @ 18 psi, 30 L/min flow, gives approximately 400 FPM velocity at the entrance to the collector and offers a more direct flow of the curtain without as much dispersion as the larger holes in previous tubing. There is no question that the particulates are captured by the air curtain, incorporated into the flow, and directed towards the collector.

4. Evaluate suction/collection system and determine the ability of the system to collect and contain the particles.

The system was set up as indicated in 4.1; "The laminar air generation tube is mounted under the leading edge of the tray and it allows the laminar air flow to be directed across the face from the forehead towards the chin and chest area and hence into the chest mounted collector."

The "A" collector from previous tests was used due to its proven performance.

Collector "A" - Basically a triangular collector with a front rectangular opening of approximately 3"(H) X 12"(W), and 7" deep with a 1 1/4" ID connecting tube at the rear. There is a "flap", approximately 12" wide X 6" deep, attached to the top section. The flap is deployed at approximately 45° and gives a deflection shield which tends to direct the particles downward into the collector.

The high volume evacuator (HVE) hose which had a suction tip flow rate of approximately 35 L/min was routed as per 4.1 and used as close to the point of particle generation as possible. This method provided the best particle control, as expected. The original premise was that we would try to control as much of the particle dispersion as possible at the source with the HVE. The laminar air curtain would then capture and direct stray particles into a collection system.

many treatment items which are not ferrous and do not lend themselves well to adding ferrous or magnetic surfaces. (ie: gauze, medicaments, etc.) A series of elastic cords were incorporated "net-like" on the tray surface and the treatment items were secured under the cords. This functioned extremely well for the most part. The only potential problem arose with the hand instruments when a larger instrument raised the cords so that smaller instruments could escape. Additional cords could easily be incorporated into the tray and lining the instrument area with magnetic material as well is certainly reasonable.

7. Illuminate the treatment areas with the fiberoptic probe and subjectively determine necessary intensity and overall effectiveness.

Again as in earlier tests, "The fiberoptic illumination probe worked extremely well. With the ambient illumination levels projected for the HMF area, the probe should provide ample light for direct and trans-illumination for a number of conditions and treatments."

Adjustment of beam intensity from the operating tray area is still desirable and should be explored on later tests.

During these tests the probe was held by the assistant and provided excellent illumination of the operative sites. It further was used as a "curing light" for the light-cured restorative resin we used on the mannequin. This was accomplished by fitting a removable blue filter to the end of the probe which gave us the necessary 550 nanometer wave length necessary for curing. A decision has yet to be made as to the definitive type of restorative materials to be recommended, however, this test does point out the viability of the resin system.

8. Use the dental engine to prepare teeth in the mannequin for restoration, in a manner consistent with normal dental treatment. Determine subjective cutting efficiency and ability of collection system to control effluent particulates (video/team).

Three teeth were prepared in the mannequin for dental restorations which were deemed probable during space flights. A front tooth was prepared to repair a simulated fracture such as might be experienced with hitting ones self in the face with a slipping wrench or tool. Two posterior teeth were prepared to treat problems which might arise from broken, or defective fillings or decayed teeth.

DISCUSSION

I am very pleased with the results to this point. With the exception of the few problems indicated above, our tests ran close to the protocol. The following observations and conclusions were made:

1. Collector "A" with the flap extended, and situated on the mannequin chest provided excellent particle control in these tests.
2. Absorbent barrier material alone does not appear to provide adequate aerosol/particulate capture.
3. The single tube laminar air curtain generator with 1 mm air holes, 20 psi, and 400 FPM air flow provides excellent particle control and direction.
4. The high volume evacuator (HVE) provides excellent particle control at the source of generation, but should not be the ONLY source of particle control. This test showed we need phase 2 (laminar air curtain and collector), and possibly phase 3 (chase cone).
5. The dental engine performed well. The final brand, configuration, power source, etc. is not as important as the function.
6. The elastic cord restraint system used on the delivery tray for retention of instruments and materials performed very well. I believe this concept should be given every consideration in the final design.
7. The tooth restorative materials handled well considering the short working time we had in the parabolas. Other materials need to be tested to determine the type of material to be recommended.

Further development and testing is necessary as outlined above. For future tests we need to consider at least the following:

1. Use a human subject to simulate actual patient restraint and positioning. (work on head positioning).
2. Provide a more rigid or "shaped" series of foot loops which may be more easily accessed from the standing position.
3. Work on the table "tethering" as was explored during this flight. The tether needs to be flexible, yet with some firmness.

went according to protocol. The basic findings from these tests were:

1. Operator/patient relationships seem to be working out OK. Foot loop restraints and table "tethers" were used during this test. The loops worked very well, once the feet were in them. The tether was a little too loose for definitive positioning, but certainly provided a stable reference point from which to work as well as providing an excellent margin of safety.
2. The basic test equipment configuration and mounting continues to work very well, was stable, and suffered only minor mechanical problems which were basically due to lack of time to fully assemble the unit after takeoff and some blockage in our aerosol lines.
3. Aerosol particles generated for the test were well contained with The suction collector and surgical suction tip.
4. The absorbent barrier, in lieu of the suction collector, did not provide adequate capture and retention of aerosols and particulates.
5. The single tube laminar air curtain, with 1 mm air holes and 20 psi air pressure, captured and directed the particles in an acceptable manner.
6. The high volume aspirator (HVE) was very efficient in capturing debris at the source of generation; again as expected.
7. The fiberoptic light probe worked extremely well.
8. The dental engine worked well, had adequate power, and appeared to have sufficient battery life to sustain working power for most any dental treatment anticipated.
9. The preparation of mannequin teeth to accept dental restorations worked very well, considering the parabola time available.
10. The dental zinc oxide and composite resin restorative materials used to repair the teeth functioned quite well. Other types of materials will be tested.

These tests were essential in that it allowed verification of the conditions observed in earlier flights and allowed visualization of the particle control system in operation with a different laminar air generator and

- Continue on with 3-way syringe.

FUTURE:

- We need to consider how the water/air separation will occur in the particle containment system.

NASA PHOTO REFERENCE

S90-28208

Demonstration of suction tip

S90-28220

Dental tray and assembly with laminar flow/particle containment system

S90-28223

Dental technique in zero-gravity

S90-28211

Demonstrating dental technique in zero-gravity